



## National High Reliability Electronics Virtual Center (HiREV) Program Update

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Activity/MECA

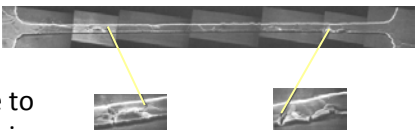
*Integrity ★ Service ★ Excellence*



# HiREV USG and Electronics Reliability

1950's

Robert Lusser states 60% of failures are due to electronic parts in Army missile systems



1960's

Failure of aluminum electrolytic capacitors start to appear in military systems.

1970's

E.M. Pohilofsky finds that gold and aluminum are leading cause of field failures in 60's and 70's

1980's IRPS



■ Wafer Level Reliability - 35%  
■ Other topics\* - 65%

1990's

The 3 top field failures in the Air Force were the result of gold embrittlement

1990's

The Army launches the Electronic Equipment Physics-of-Failure Project

2000's

Dielectric failures are proving to be the leading cause for transistor failures in smaller node sizes

2009

HSC on orbit failure



1960's



The Minuteman System cost is \$30,000,000 for parts improvement by improving processing methods and for reliability testing . RDT&E annual budget is only \$16,000,000 for electronic components.

1960's

J.R. Black publishes first paper on electromigration

1970's

First evidence of hot electrons

1980's

Space shuttle flight is aborted due to IC reliability failure



2010

NBTI degradation not permanent! NBTI is proving to be one of the most important reliability issue in scaling electronics.

1990's IRPS

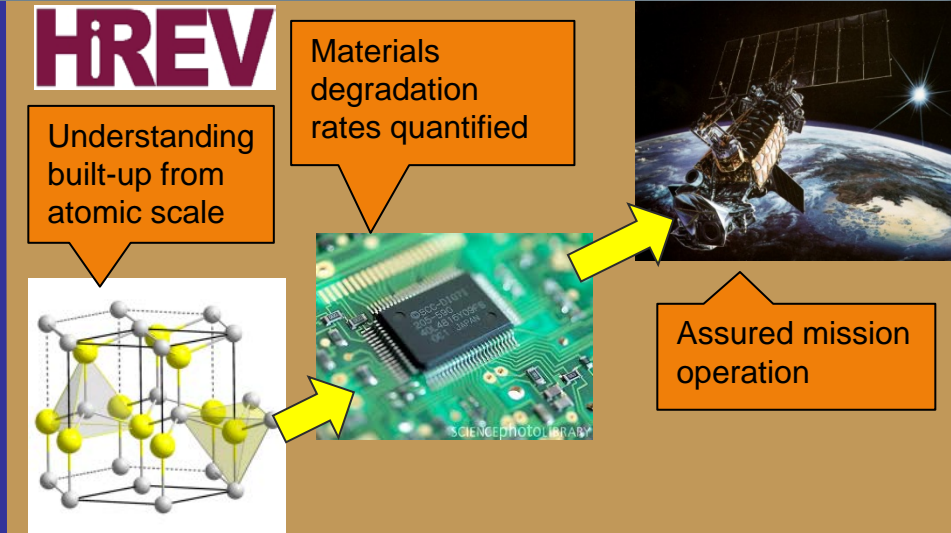


■ Wafer Level Reliability - 42%  
■ Other topics - 58%

*\*Note: Other topics include packaging, design for reliability and process*  
G.H. Ebel, "Reliability Physics in electronics: A Historical View",  
IEEE Transactions on Reliability, Vol. 47, NO. 3-SP 1998, pp379-389

## MOTIVATION

- Recent costly electronics failures in DoD and Space programs highlighted need for government led quantitative risk assessments and lifetime prediction capability
- NSS acquisition community forced to use highly-accelerated tests that are unlikely to correlate with operational use
- Customers: USG, US Space Programs and others inserting emerging electronics
- Gov. organizations in current economic climate can not afford to duplicate efforts and are limited by time and resources.
- "Close collaborations" are essential to maximize success



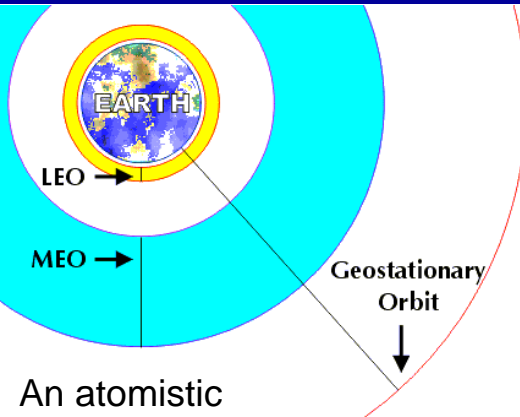
## TECHNICAL IDEAS

- Physics-based approach to replace current practice of statistics-driven projections
- Characterization of atomistic and interfacial phenomena in electronics — identify degradation mechanisms and rate of change
- Develop and apply multi-scale materials models — model and simulate degradation rates

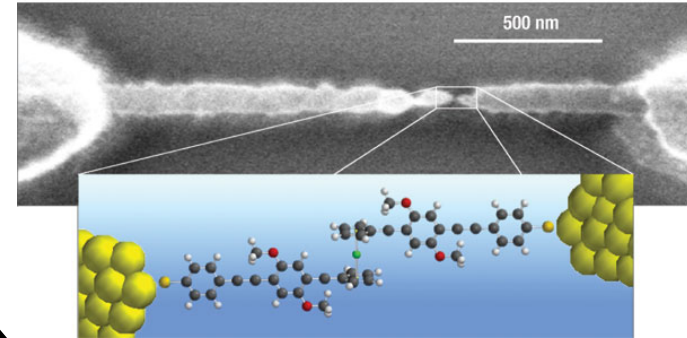
## HiREV PAYOFF

- **Near-term** – Validated government owned lifetime analysis for acquisition decisions
- **Mid-term**- Updated practices (standards, guides, specs and methods)
- **Long-term**-Decreased anomalies due to poorly understood electronics
- **Risks** – Difficult problem – Requires discovery
- **Costs** – Function of device technologies

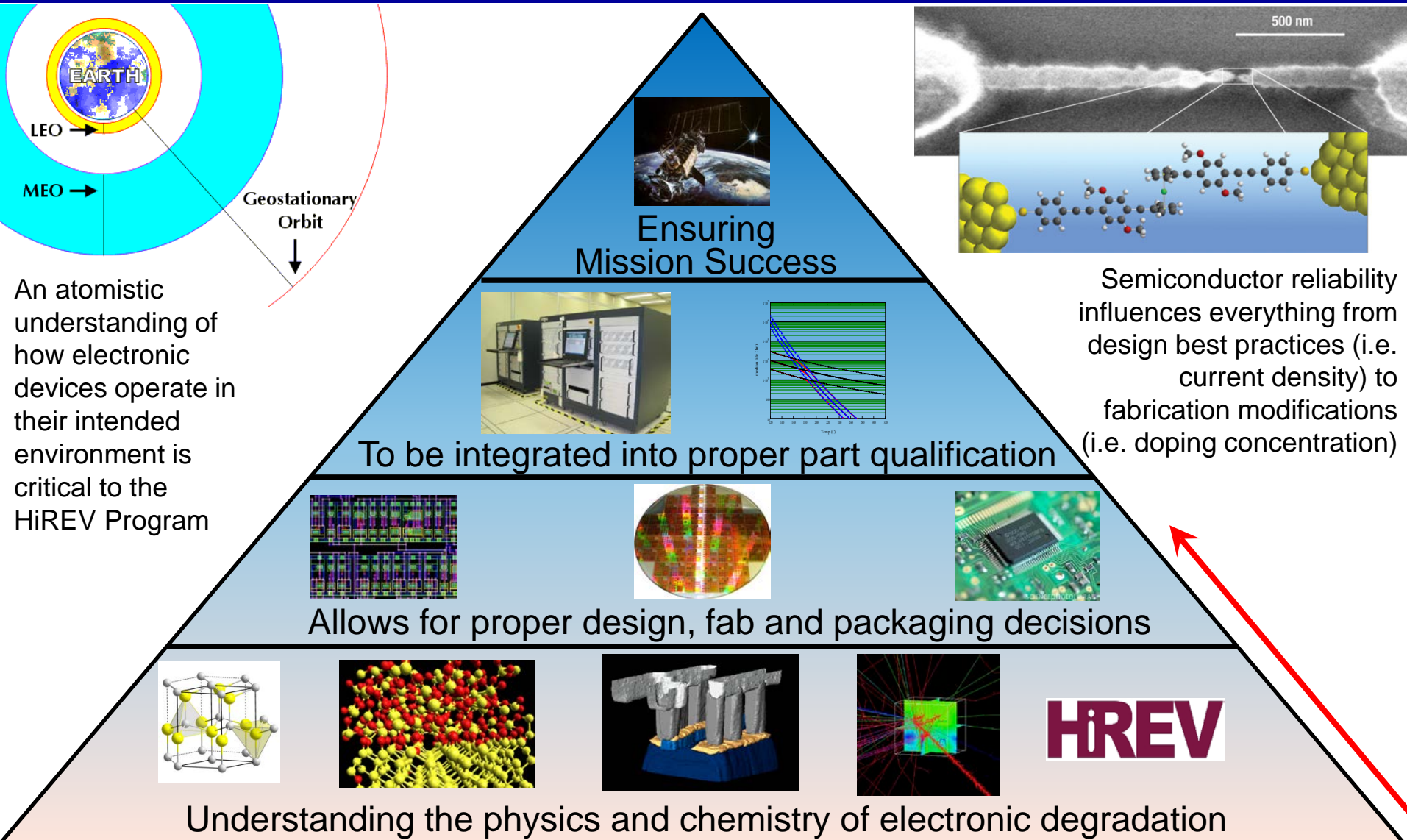
## How HiREV Influences Mission Success



An atomistic understanding of how electronic devices operate in their intended environment is critical to the HiREV Program

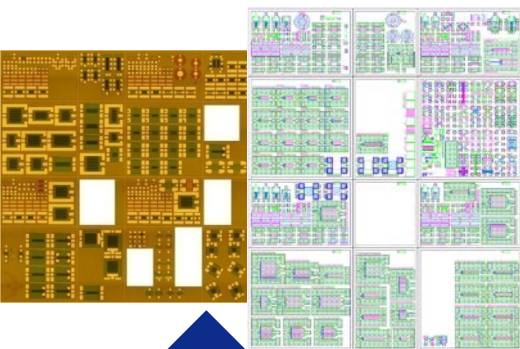


Semiconductor reliability influences everything from design best practices (i.e. current density) to fabrication modifications (i.e. doping concentration)





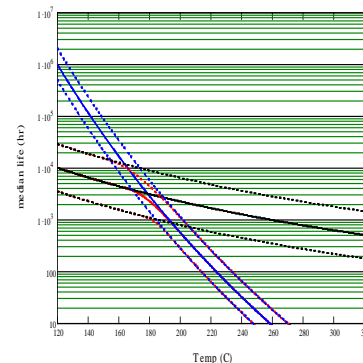
Device Foundry



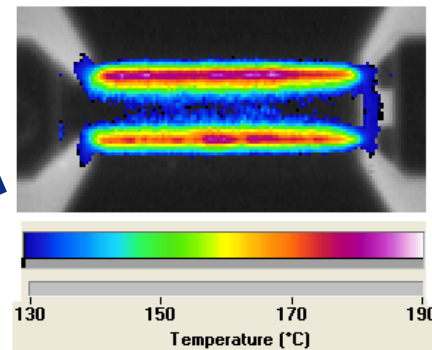
Device Stress Test



Reliability Mathematics

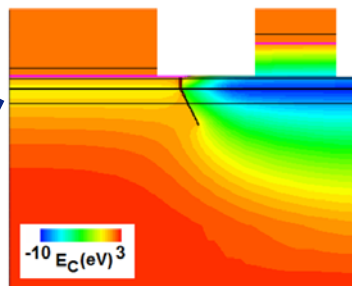


Device Thermography & Thermometry

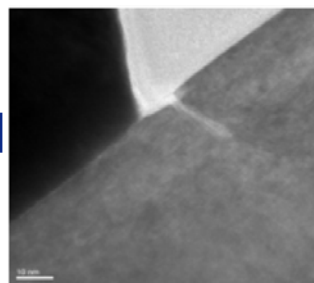


## CLOSING THE LOOP

Electrothermal Modeling



Structural Analysis



Packaging Integrity

## HiREV

- Technology forecasting (US Government needs)
- POF tools for Si and III-V electronics
- Pre-qualification efforts on
  - Base Metal Electrode (BME) Capacitors
  - Class Y packages
  - 45 and 90nm CMOS trusted foundry technology
- Reliability science
  - GaN technology
- Reliable Electronics
  - Electronic technology Physics of Failure (PoF)
- Radiation Reliability of Electronics
  - Modeling PoF in new technologies

## NEPP

- Body of Knowledge (BOK) documents on new technologies
- Guideline on testing/qualification of FPGAs, memories, BME capacitors
- Evaluation of commercial products
  - BME capacitors
  - GaN/SiC devices
  - FPGAs
  - Automotive-grade electronics
- Reliable Electronics
  - Applying PoF to qualification/usage guidance
- Radiation Reliability
  - Testing for PoF on new Technologies
  - Support modeling/tools on new technologies
  - Qualification/usage guidance

**HiREV utilizes test structures for detailed knowledge (model first)**

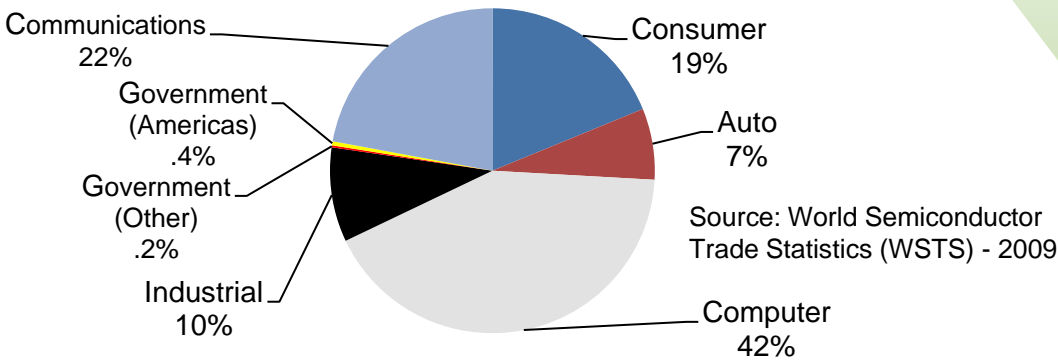
**NEPP utilizes commercial product for general knowledge (test first)**

**HiREV PoF on early TRL's feeds NEPP focus on insertion/qualification**

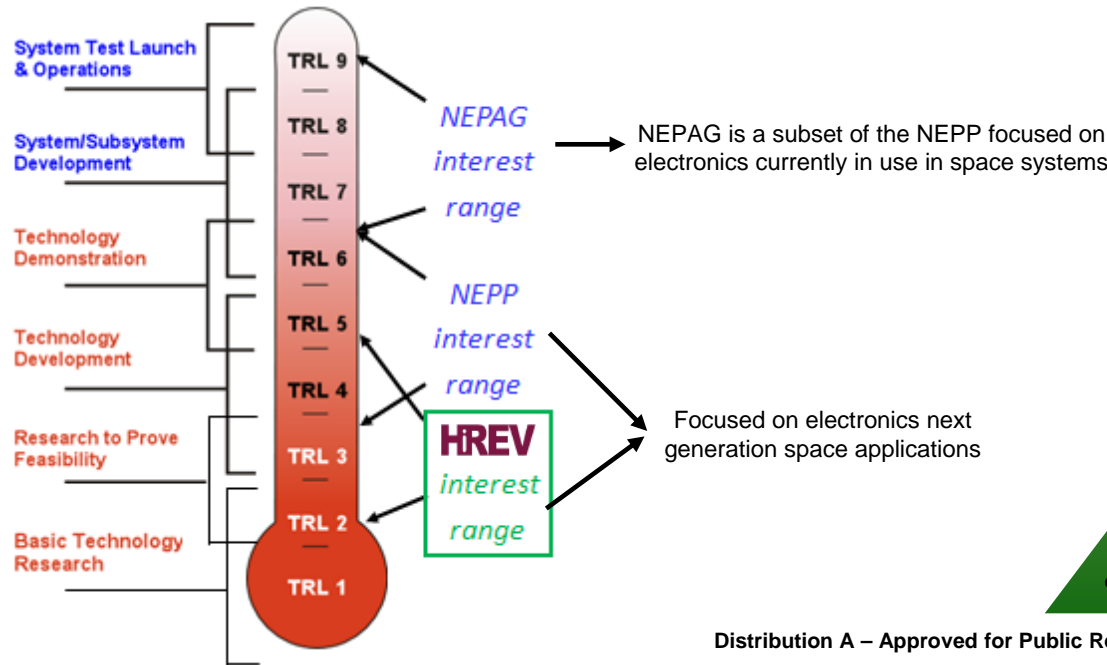


## Inputs/Outputs to HiREV

### Semiconductor End-Use by Worldwide Total



Military/Aerospace (Mil/Aero) Grade Electronics less than 0.1% of the total commercial electronics market



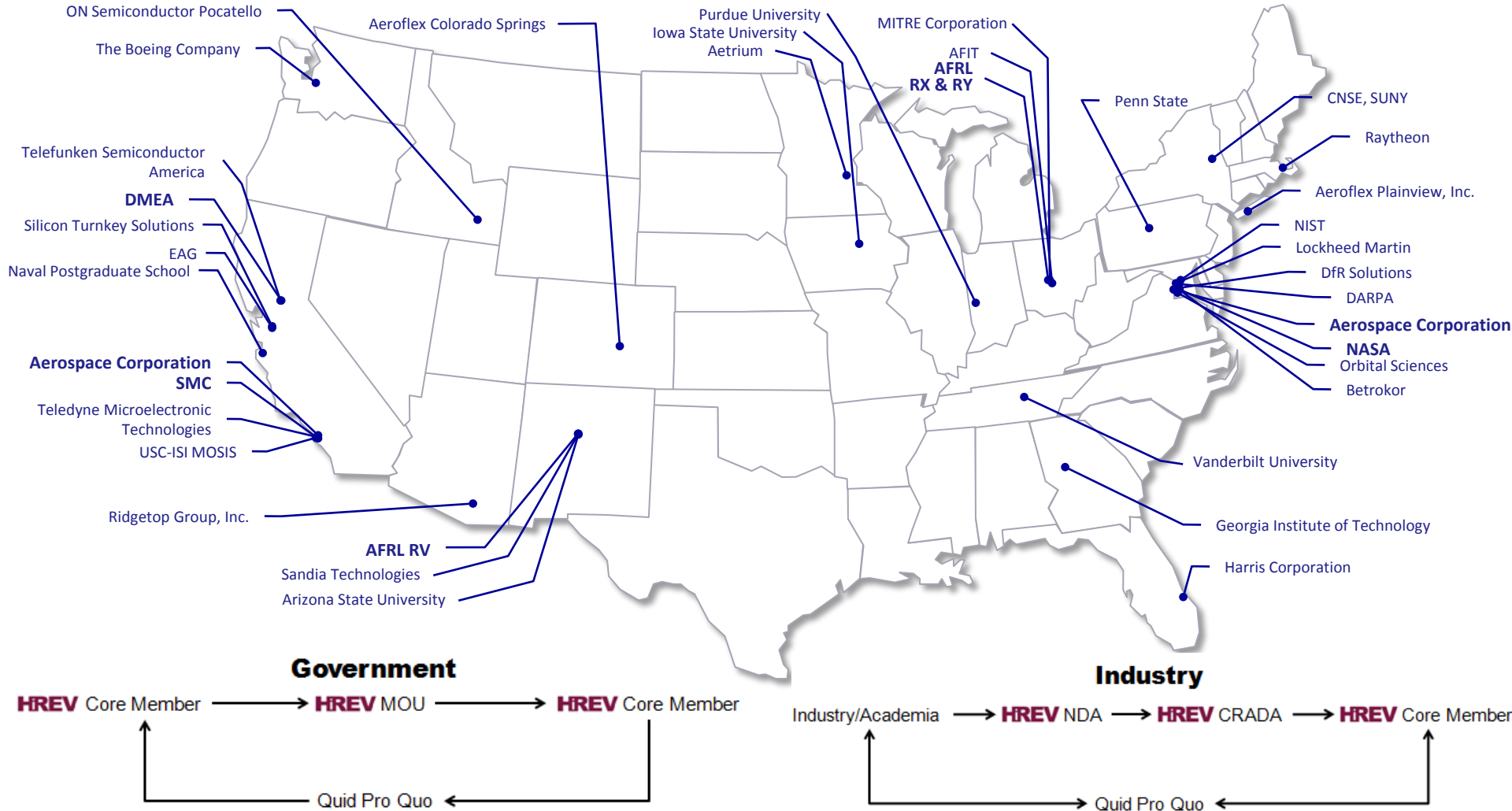
### Inputs

- Technology Insertion roadmaps of: NSS, MDA, NASA & Services
- Research Outputs from: Academia, Government and Industry

# HiREV

- Qualification Guidelines
- Integrated Technology Roadmaps
- Technology Specific Expertise
- Updates to Specs & Standards
- Lower Technology Insertion Risk
- Pre-Qual Data (Reliability, Radiation)

### Outputs



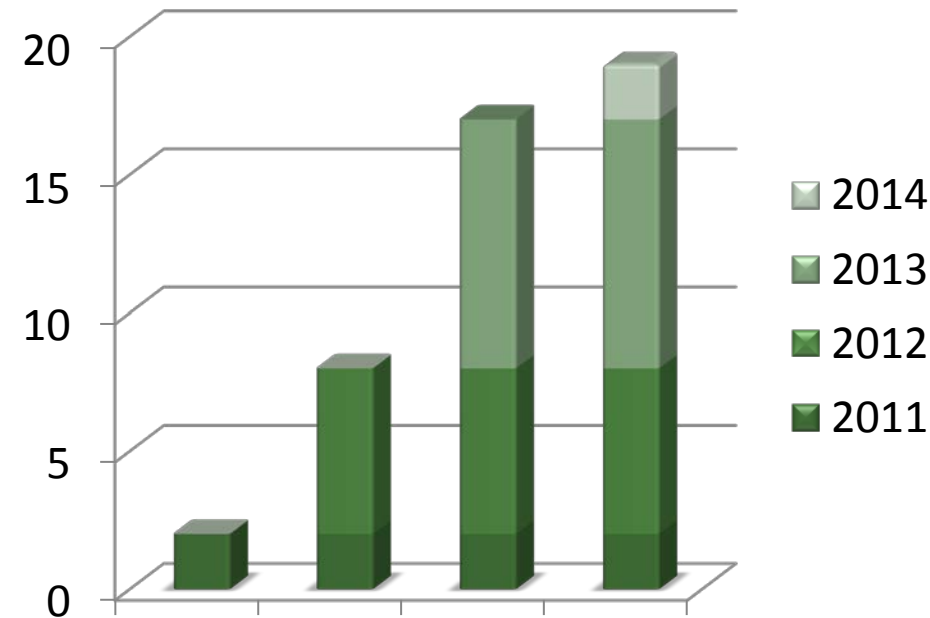
With a **VIRTUAL** foundation this concept allows for the government to leverage off of each others capabilities as well as industry to provide a low cost solution to an expensive problem



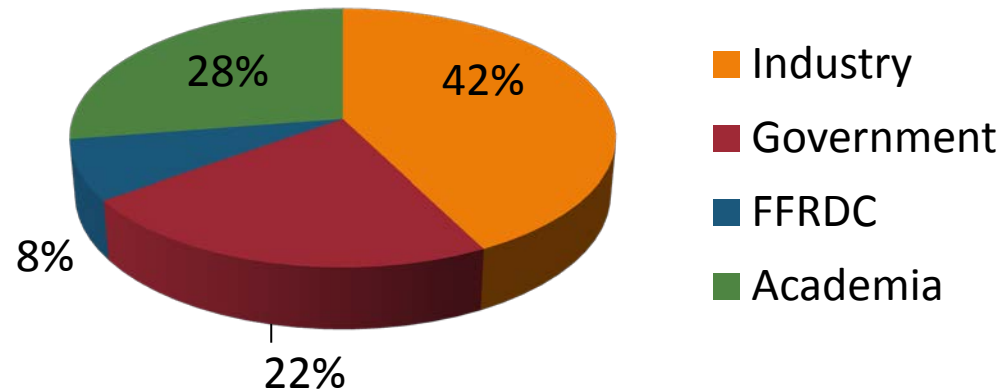
## Growth of the HiREV program



Signed NDA's

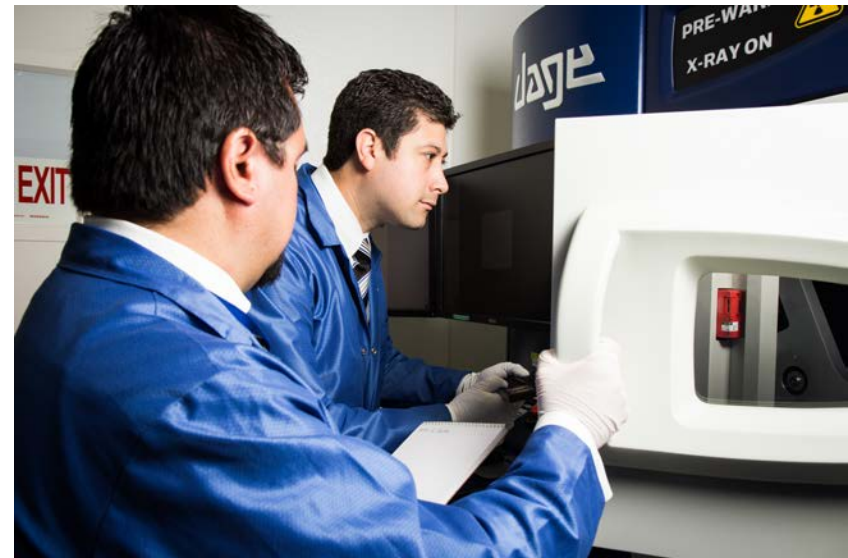
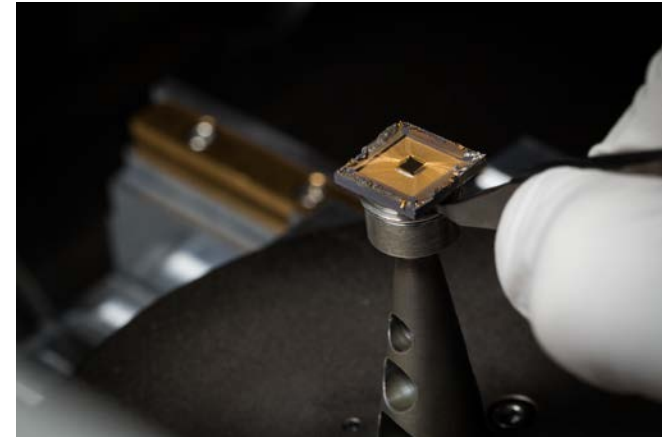


HiREV Program Engagement Distribution



Government led reliability effort has proven to be needed based on both Industry and Academia's interaction with HiREV

- **DARPA IRIS**
  - Government teams value to DARPA
- **CALM 90 development**
  - Industry/HiREV Interaction on EM tool
  - Development of models for HCI, TDDB and NBTI
  - Break Out Session
- **Technology Forecast TOR**
  - Radiation Test Infrastructure Study
- **Key Note Speech at GOMACTech**
  - Al Shaffer
- **BME Capacitors**
- **NPS/DMEA/AFRL PhD support**
- **Quid Pro Quo Utilization**
  - Ridgetop Group
  - Boeing SSEd
  - Aerospace Corporation



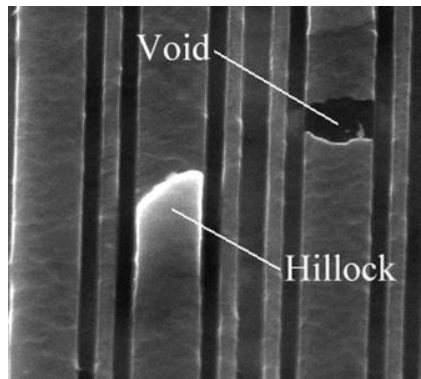


- **HiREV continues to build success**
  - **Has overcame government funding cut restrictions**
- **R&D Communities looking for ways to collaborate**
- **Wrap up of DARPA IRIS Program**
- **Continued Development of CALM 90nm tool**
- **Continued evaluation of emerging technologies**

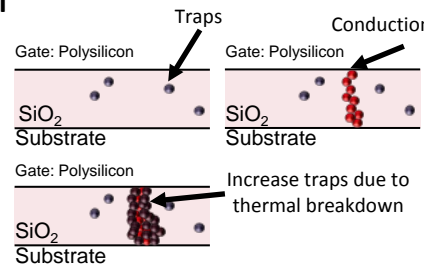


## Rapid Pace of Part Evolution

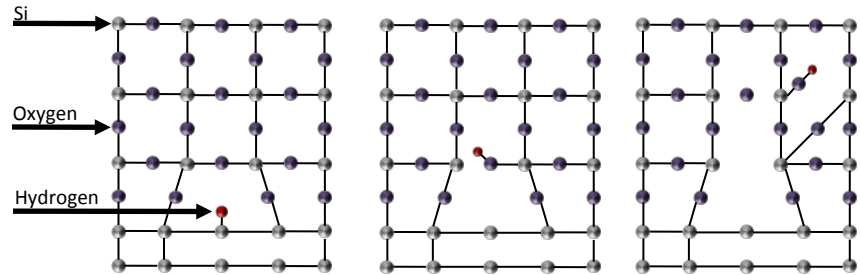
Chip speeds increase with decrease in transistor size. As transistor sizes decrease the physics of failure for transistors becomes even more important.



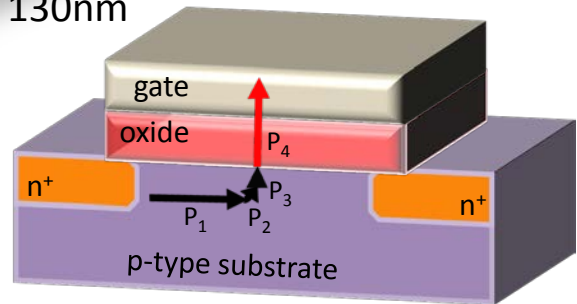
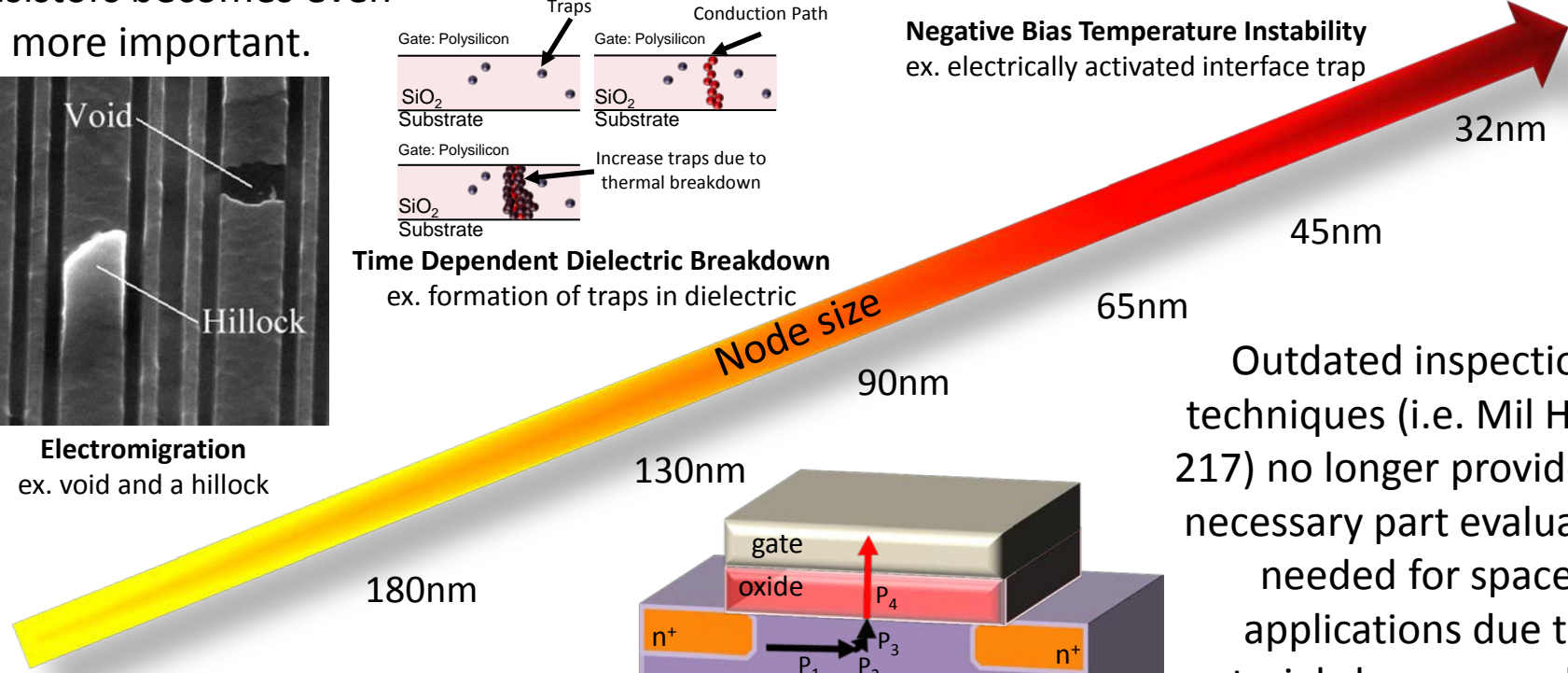
**Electromigration**  
ex. void and a hillock



**Time Dependent Dielectric Breakdown**  
ex. formation of traps in dielectric



**Negative Bias Temperature Instability**  
ex. electrically activated interface trap



**Hot Carrier Injection**  
ex. lucky electron model

Outdated inspection techniques (i.e. Mil HDBK 217) no longer provide the necessary part evaluation needed for space applications due to material changes made for part miniaturization.



## Background

- ✓ Allows for accelerated advancements of semiconductor reliability science and engineering methods
- ✓ Government organizations reliability portfolio leverages the overall HiREV programs capabilities.
- ✓ HiREV has entered into 11 CRADA agreements with large and small IC suppliers across both basic and applied research facilities in order to conduct reliability science evaluations.
- ✓ CRADAs allow for a “Quid Pro Quo” relationship between government laboratories, prime contractors, academia, and n<sup>th</sup> tier suppliers.

## Benefits

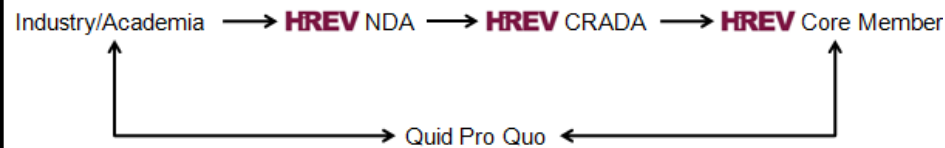
HiREV works towards ensuring the timely delivery of independent, high-fidelity lifetime estimates for electronics device technologies and their corresponding underlying physics and chemistry of operation and failure to enable their qualification for US Space Programs.

Preserve knowledge in updated lifetime models, standards, practices, processes and techniques for industry – encourage industry participation.

## Government

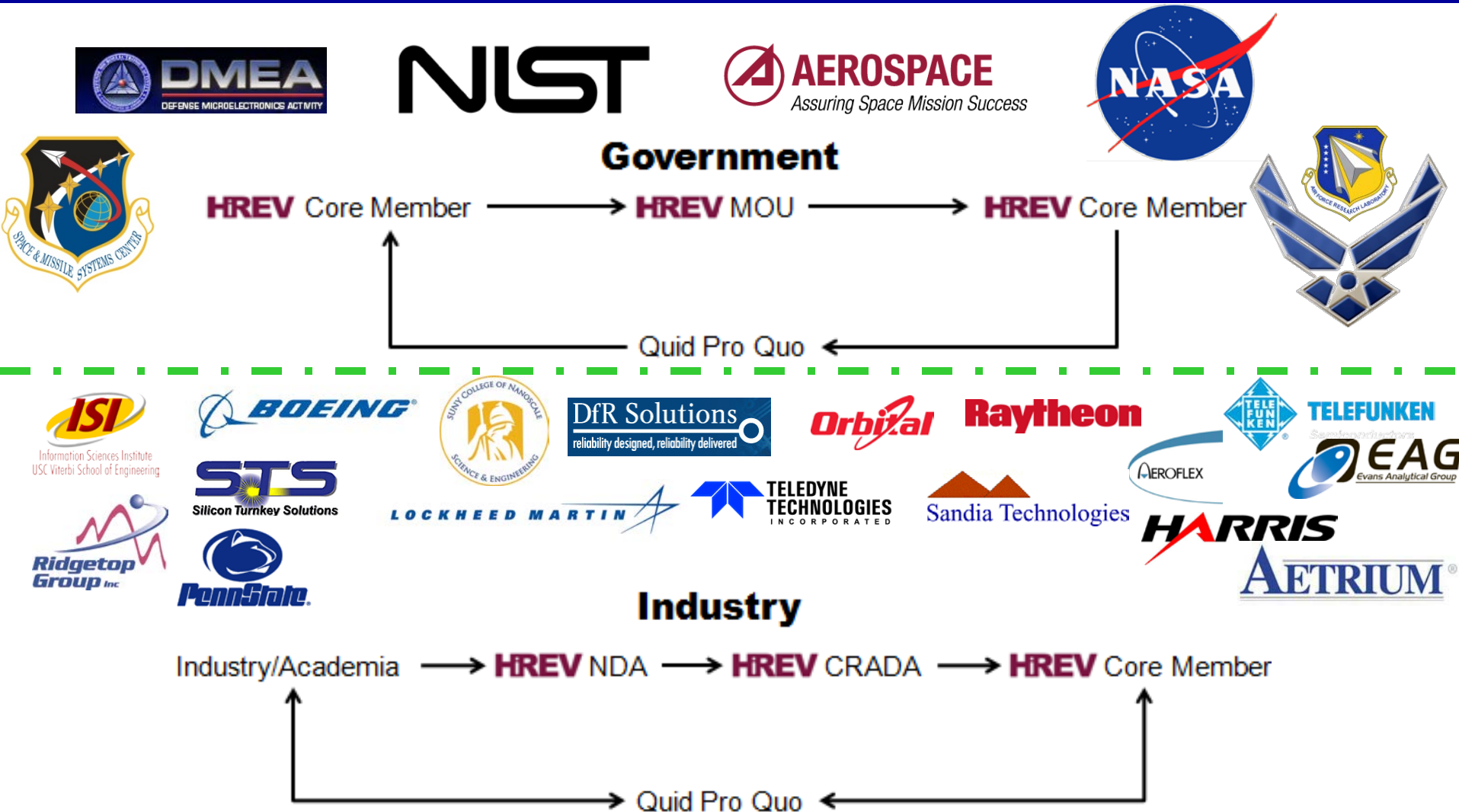


## Industry



## Quid Pro Quo - Selected Success Stories

- ✓ The Ridgetop Group leverages AFRL/RV QFI tool to thermally image reliability canary structures
- ✓ AFRL/RV provides DMEA 130nm wafer fabricated at IBM with reliability test coupons which supports Negative Bias Temperature Instability and Total Ionizing Dose synergistic effects research.
- ✓ Aerospace Corporation provides DMEA dual beam FIB 3D reconstruction model of PIC-16 component to enhance DMEA's Reverse Engineering capabilities.
- ✓ Boeing SSED evaluates resistance measurements for the HiREV CALM 90nm tool.



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